Weather Note

RADAR ECHO OF A MOUNTAIN WAVE ON FEBRUARY 15, 1960

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1. INTRODUCTION

There have been many descriptive accounts of mountain wave cloud patterns, but to our knowledge such clouds have not been previously observed on radar. Since the new WSR–57 radar has been installed at Washington National Airport, the authors have been watching wave situations to see if some indications could be seen on the radar. At 1330 EST on February 15, 1960, a wave cloud pattern was observed on the range-height-indicator (RHI) scope. Figure 1 shows a Polaroid picture of the radar scope.

2. OBSERVED EVIDENCE OF THE WAVE

On the previous day, perfectly formed standing wave lenticular altocumulus clouds were observed overhead and to the northwest of Washington around 1330 EST following a general clearing after snow had ended in the area. The clouds were oriented northeast-southwest and at least four waves were observed. These lasted until around 1700 EST by which time most of the clouds had dissipated.

Considering the fact that conditions were again favorable for wave formation on the morning of February 15, it was not surprising that a Navion reported severe turbulence at 10,000 feet over Frederick, Md. at 0800 EST. A Martin 404 reported severe turbulence at 7,000 feet over Albany, N.Y. at 0815 EST. Lynchburg, Va. reported standing wave lenticular altocumulus clouds to the north over the mountains from 1100 to 1400 EST. Several other stations reported lenticular altocumulus clouds. A strong downdraft was reported by a DC–3 at 6,000 feet southwest of Montpelier, Vt. at 0859 EST. Martinsburg, W. Va. reported scattered clouds at 8,000 feet and overcast conditions at 12,000 feet. See figure 2.

The clouds as viewed from Washington National Airport were altocumulus floccus with a considerable amount of virga in the form of snow. The snow seemed to fall straight from the clouds and then trail away to the southeast. The clouds, whose tops appeared to be very flat, extended as far west as could be seen. By late afternoon, there appeared to be two rows of wave-shaped clouds to the west. Smaller fragments of the altocumulus clouds continued to drift eastward but none reached the area over the airport.

3. WAVES AS SHOWN ON THE RHI SCOPE

The photograph of the RHI scope (fig. 1) shows that the top of the echoes was near 18,000 feet. The height of the bases apparently increased from 7,000 feet on the western end to about 12,000 feet at the eastern end with the cells becoming smaller to the east. The picture shows 8, to possibly 11, waves spaced about 3½ miles apart with a missing echo between the last two cells at the eastern end. The gap may simply mean that this cell was quite weak and was dissipating as fast as it could form or that the air was locally quite dry in this region. The last broad echo over the mountains to the west of Martinsburg, with tops around 14,000 feet, appears to be from an area of more general cloudiness possibly with precipitation reaching to near the ground.

4. SUPPORTING UPPER AIR DATA

Because the observed weather and cloud patterns overhead at the Washington National Airport were decidedly different from those to the west, it is felt that the Wash-

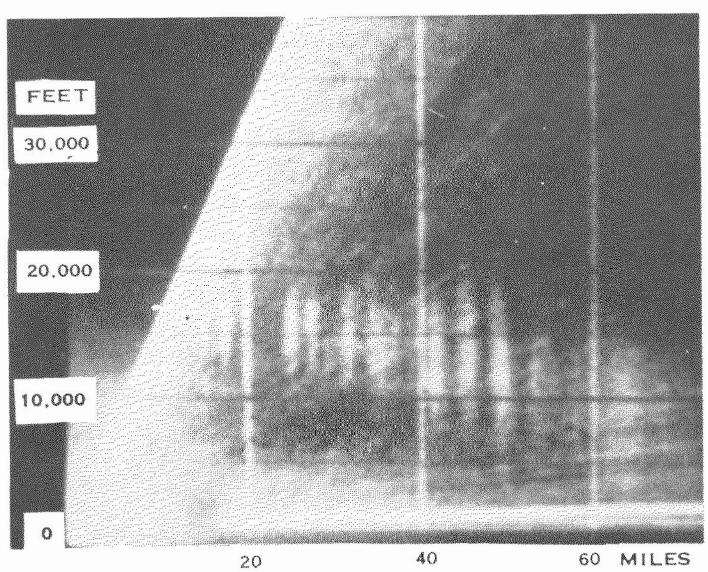

FIGURE 1.—Radar scope presentation, 1330 EST, February 15, 1960, at Washington National Airport, Washington, D.C.

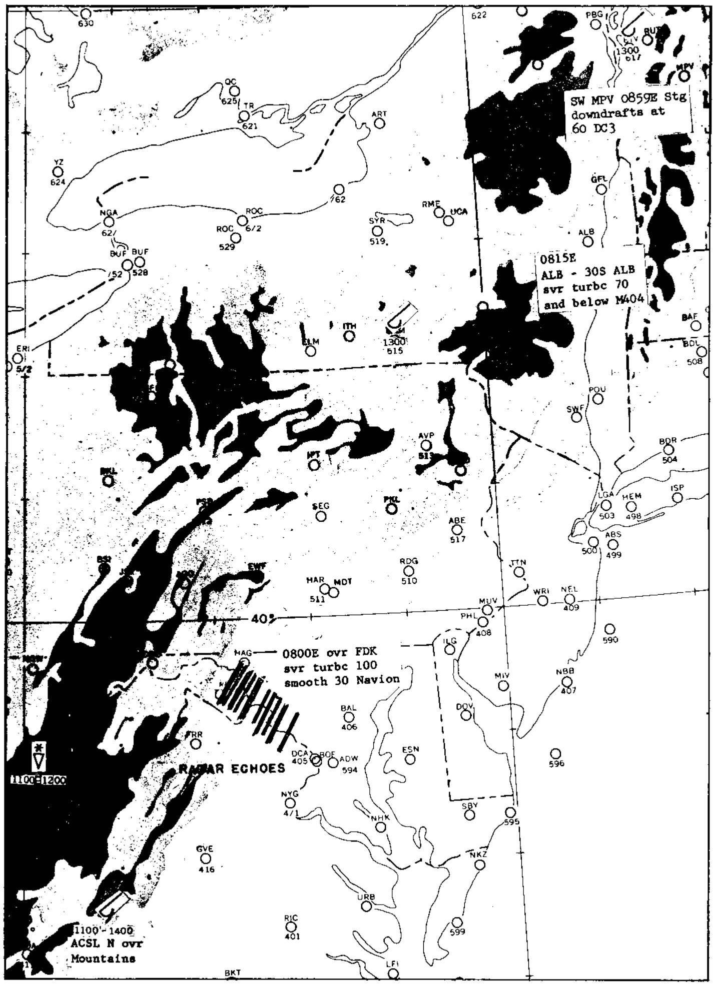

FIGURE 2.—Map showing the observations indicating turbulence on the morning of February 15, 1960 and the plotted position of the radar echoes seen at Washington. Shading shows topography.

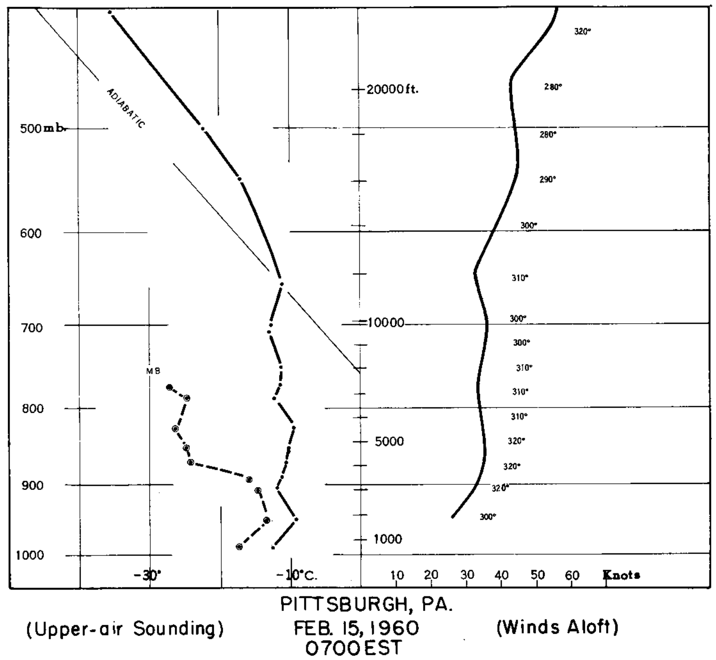

FIGURE 3.—Upper air sounding and winds aloft at Pittsburgh, Pa.

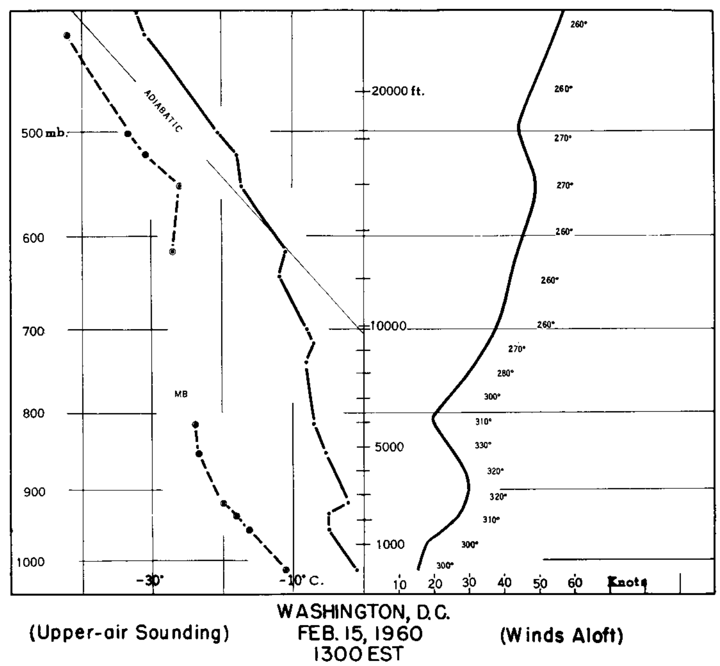

FIGURE 4.—Upper air sounding and winds aloft at Washington, D.C.

ington sounding was not very representative of the echo area. The nearest soundings were the Pittsburgh 0700 EST and the Washington 1300 EST observations. The sounding at Pittsburgh (fig. 3) showed several stable layers from the surface up to 7,000 feet and between 10,000 and 12,000 feet with increasing winds above 12,000 feet. If the moisture, as indicated on the morning Pittsburgh sounding, was lifted to saturation, clouds similar to those shown on the radar could have been produced.

The Washington sounding (fig. 4) taken at 1300 EST showed stable layers from 6,000 to 10,000 feet, and again at the 13,000 and 17,000-foot levels with a decided increase in wind speed above 6,000 feet. The air was quite dry between 6,000 and 13,000 feet.

Work by Scorer [5] shows the importance of atmospheric stability in the establishment of waves. His stability term is given by $l^2=g\beta/U^2$, where U is the wind speed, β the static stability, and g is gravity acceleration. According to Scorer l^2 should decrease in the upper layer over that in the lower layer. In this case for the 1300 EST Washington sounding l^2 was equal to an average of 3.2 below 10,000 feet and 0.6 above that level. For the 0700 EST Pittsburgh sounding l^2 was equal to an average of 2.3 below 12,000 feet and 0.7 above that level.

On this particular day a strong jet stream was oriented in about a west-east direction over southern Virginia. Colson [1] pointed out that the presence of a strong jet stream in the higher levels is the most probable situation giving rise to the strong wind shear which is essential in the formation of mountain waves.

On the assumption of increasing moisture in the middle layers as the air moved eastward and the strengthening of the inversion near the 10,000-foot level as indicated on the Pittsburgh sounding, along with the stronger wind speeds and wind shear as indicated on the Washington sounding, a computation of the wavelength of billow clouds using the equations developed by Haurwitz [3, 4] gives values of the wavelength of the correct order of magnitude, 2 to 3 miles. The wavelength observed on the RHI scope was approximately 3½ miles. In another report on a very prominent wave cloud system in this area by Colson and Lindsay [2], the wavelength was computed to be about 4 miles.

5. CAPABILITIES OF THE WSR-57 RADAR

Much valuable information can be derived from the radar equipped with the RHI scope. Through its use a three-dimensional representation or interpretation of the radar echoes can be made. However, there are several factors which must be taken into account before definite quantitative measurements can be made. These include the characteristics of the particular radar set, the nature of the echoes, corrections for earth's curvature and beam width distortion. In making these corrections one must be sure that the targets are filling the radar beam and that the normal signal propagation is maintained. The problem of getting a representative picture of all of the targets at one time is difficult because if only the edge of a target is being scanned, it will appear noticeably smaller or weaker than other targets more completely in the beam. However, it was not felt worth while to make the detailed corrections in this case, since we are mainly interested in a qualitative interpretation of the radar picture.

Because of the vertical motions involved in the formation of wave clouds, these can support larger water droplets than ordinary altocumulus clouds and are better targets for the radar beam. The ability of radar to indicate the location and extent of wave phenomena could be a useful tool in aviation forecasting. Mountain waves present a serious hazard to small aircraft and also to larger aircraft whose operational requirements demand that flights be made at levels close to the terrain. In some cases, mountain waves generate severe turbulence and strong updrafts and downdrafts.

6. CONCLUSIONS

The results of observations during the past years indicate that the mountain wave situations can be rather widespread and particularly frequent during the winter months east of the Appalachians. Further efforts will be made at Washington National Airport to obtain additional data of this nature to determine the possibilities of radar in the detection of wave clouds.

REFERENCES

1. D. Colson, "Meteorological Problems in Forecasting Mountain Waves," *Bulletin of the American Meteorological Society*, vol. 35, No. 8, Oct. 1954, pp. 363–371.
2. D. Colson and C. V. Lindsay, "Unusual Wave Cloud Over Washington, D.C.," *Monthly Weather Review*, vol. 87, No. 12, Dec. 1959, pp. 451–452.
3. B. Haurwitz, "Über die Wellenlänge von Luftwogen," *Beiträge zur Geophysik*, vol. 37, 1932, pp. 16–24.
4. B. Haurwitz, "Wogenwolken and Luftwogen," *Meteorologische Zeitschrift*, vol. 48, 1931, pp. 483–484.
5. R. S. Scorer, "Theory of Waves in the Lee of Mountains," *Quarterly Journal of the Royal Meteorological Society*, vol. 75, No. 374, Jan. 1949, pp. 41–56.

CORRECTION

Monthly Weather Review, vol. 88, Aug. 1960, pp. 290–291: In Section 4, Monthly Mean 700-mb. Circulation, the reference to the map of monthly mean circulation in line 2 should be to figure 7; the figure referred to in line 8 from the bottom of that column should be figure 6. P. 291, line 8, col. 1: reference should be to figure 7.